Electric reactive Armour.

An electric reactive armour (10) comprises a first electrode (1) and a second electrode (2) spaced apart from the first electrode, to which electrodes (1, 2) a high voltage can be applied so as to disrupt a charge contacting the electrodes. The second electrode (2) comprises an electrically conductive structure (21) having a plurality of surfaces (22) embedded in an insulating material (23), such that the charge jet penetrates successive surfaces of the electrically conductive structure. The electrically conductive structure (21) comprises a meandering structure and/or a structure of linked cavities, such as a honeycomb structure.
The present invention relates to electric reactive armour (ELRA).

More in particular, the present invention relates to an electric reactive armour, comprising a first electrode and a second electrode spaced apart from the first electrode, to which electrodes a high voltage can be applied so as to disrupt a charge contacting the electrodes. Such an armour is known from European Patent EP 1 877 720 & United States Patent US 8 006 607 (Fraunhofer-Gesellschaft).

The known armour is designed to protect an object from threats such as shaped charges, for example RPGs (Rocket Propelled Grenades). On impact, the charge of an RPG produces a high speed jet of typically molten metal, which has a high penetrating power. As a high voltage is applied to the electrodes, the jet effectively creates a short circuit when it has penetrated the first electrode and reaches the second electrode. As a result, a strong electrical current will flow through the jet. This strong current resulting from the short circuit disturbs the jet and distorts its needle shape, thus significantly reducing its penetrating power.

European Patent EP 1 877 720 mentioned above discloses a second electrode which is made of a spatially heterogeneous material, such as open-pore aluminium foam. The patent states that the electrode material should have a very good electrical conductivity. Using such a spatially heterogeneous electrode material apparently causes electrode material to be displaced in a direction away from the longitudinal axis of the jet, thus increasing the disturbance of the jet. However, it has been found that this disturbance of the jet can be improved upon and that more effective disturbance arrangements are possible.

It is an object of the present invention to overcome these and other problems of the Prior Art and to provide an electric reactive armour which causes a very effective disturbance of the shaped charge jet.
Accordingly, the present invention provides an electric reactive armour, comprising a first electrode and a second electrode electrically insulated from the first electrode, to which electrodes a high voltage can be applied so as to disrupt a charge contacting the electrodes, which armour is characterised in that the second electrode comprises an electrically conductive structure having a plurality of surfaces embedded in an insulating material, such that the charge penetrates successive surfaces of the electrically conductive structure.

By providing an electrically conductive structure having a plurality of surfaces embedded in an insulating material, such that the charge penetrates successive surfaces of the electrically conductive structure, it is accomplished that the electrical point of contact of the jet is renewed in a stepwise manner without interrupting the current. This stepwise renewal of the point of contact causes the initially needle-shaped jet to form a series of relatively broad discs. That is, the electrical current caused by the stepwise penetration distorts the jet in such a manner, that it is blunted and effectively fragmented. As a result, the second electrode is penetrated over a smaller distance and the jet may be stopped altogether.

The conductive structure also causes an early onset of the current, which further assists in the distortion of the jet.

In a first embodiment, the electrically conductive structure comprises a meandering structure. Such a meandering structure preferably has main surfaces which extend substantially parallel to each other, which main surfaces are connected by curved surfaces and/or by surfaces arranged at an angle of, for example, 90° relative to the main surfaces. A meandering structure has the advantage of being simple yet effective.

In a second embodiment, the electrically conductive structure comprises a structure of linked cavities, such as a honeycomb structure. Each cavity may extend substantially through the width of the structure, or
may be small relative to said width, and is on several sides surrounded by conductive surfaces.

In an advantageous embodiment, the electrically conductive structure comprises a plurality of electrically conductive elements made of conductive foil, such as metal foil. The electrically conductive elements may each constitute a hexagonal cylinder or a hexagonal torus. In such embodiments, the conductive structure may be constituted by stacking three-dimensional elements, such as cylinders. It is noted that other embodiments, such as the meandering conductive structure mentioned above, may also be made of conductive foil.

In preferred embodiments, the second electrode further comprises a base element on which the electrically conductive structure is mounted and to which it is electrically connected, which base element preferably comprises a solid metal plate. In these embodiments, the second electrode is constituted by both an embedded conductive structure for disrupting the charge, and a metal plate for providing mechanical protection. It will be understood that the embedded conductive structure is mounted in the base element in such a way that the structure faces the jet, so that the jet will reach the structure before it reaches the base element.

The present invention also provides an armour as defined above, further comprising a stripper plate arranged between the first electrode and the second electrode for reducing the width of the charge and/or for providing further mechanical resistance. The stripper plate may, for example, be made of metal, such as armour quality metal.

The present invention further provides a system for protecting a vehicle or vessel, the system comprising at least one high voltage source and an electric reactive armour as defined above.

The present invention still further provides a vehicle or vessel provided with a system as defined above.
The present invention additionally provides a method of protecting a vehicle or a vessel, the method comprising the step of applying a system as defined above.

The present invention will further be explained below with reference to exemplary embodiments illustrated in the accompanying drawings, in which:

Fig. 1 schematically shows an embodiment of an electric reactive armour according to the present invention.

Fig. 2 schematically shows an alternative embodiment of an electric reactive armour according to the present invention, provided with a stripper plate.

Figs. 3a-3g schematically show various embodiments of the electrically conductive structure according to the present invention.

Fig. 4a-4c schematically show various embodiments of arrangements of surfaces for use in the electrically conductive structure according to the present invention.

The electric reactive armour (ELRA) 10 shown merely by way of non-limiting example in Fig. 1 comprises a first electrode 1 and a second electrode 2, which electrodes are spaced apart at a distance \((D+d)\). A high electric voltage can be applied to the electrodes using a suitable electrical power source (not shown), such as a capacitor. Typical suitable voltages range between 1000 and 5000 V, depending on the application and on the dimensioning of the armour. The power source should be capable of supplying a strong current during a short period of time, for example 100 to 500 kA during 100 \(\mu\)s, or 1000 kA during 50 \(\mu\)s. Again, the current to be supplied will depend on the application and the dimensioning of the armour.
In a typical application, the first electrode 1 will face away from the object to be protected, while the second electrode 2 will face towards said object. In the embodiment shown in Fig. 1, the first electrode 1 is constituted by a metal plate, made of armour quality metal. The second electrode 2 of Fig. 1 also comprises a metal plate 29, which preferably is also made of armour quality metal so as to resist bullets and other projectiles.

Some projectiles, however, are capable of producing a jet of molten metal upon impact. Such projectiles may be rocket propelled grenades (RPGs), the charge of which typically produces such a jet. Most armour plates are not capable of withstanding such charges, unless the plates are very thick. However, thick armour plates are necessarily heavy, and make it unfeasible to use such thick plates in vehicles and small vessels. Electric reactive armour (ELRA) is designed to disrupt the jet of a charge as it penetrates the armour. The electric reactive armour of the present invention is designed to disrupt the jet even more.

As shown in Fig. 1, the jet 7 of a charge penetrates the first electrode 1. According to the present invention, the second electrode 2 comprises a series of arrangements 20, 20', 20" ..., each constituted by an electrically conductive structure 21 having a plurality of surfaces 22 embedded in an insulating material 23. The surfaces 22 need not be designed to resist charges. Instead, the surfaces 22 are designed to be penetrated by the jet 7. However, a certain resistance to the jet 7 may be desirable in some embodiments. In preferred embodiments, however, the surfaces 22, 22', ..., and typically the entire structure 21, is made of relatively thin conductive foil. It is noted that these surfaces are substantially parallel to the base plate 29 of the second electrode 2. It is further noted that the electrically conductive structure 21 is both mechanically and electrically connected to the (electrically conducting) base element 29 at connecting points 25.
When the jet starts penetrating the second electrode of the present invention, it first penetrates the electrically insulating material and then reaches the first surface 22 of the electrically conductive structure 21. As this electrically conductive structure is part of the second electrode 2, it is electrically connected to the power source mentioned above. Accordingly, the jet 7 will short-circuit the electrodes 1 and 2, thus causing a strong electrical current to flow through the jet. This strong current generates strong electromechanical forces which distort the jet due to, but initially not sufficiently to stop the jet from further penetrating the arrangement 20.

This further penetration will cause the jet to reach the next surface 22’, thus also causing a short-circuit via the next surface. Meanwhile, the first surface 22 will be at least partially destroyed by the jet 7. The point of contact between the jet 7 and the surface 22 is likely to have evaporated (and become a plasma). However, due to the next surface 22’ being contacted by the jet 7, it is no longer necessary for the first surface 22 to conduct the current. The current through the jet commutates from the point of contact with surface 22 to the next point of contact with surface 22’. Thus a substantially continuous flow of current is guaranteed. Meanwhile, the length of the current path through the conductive structure decreases, thus reducing its electrical resistance and thereby increasing the current.

This process of the jet 7 penetrating successive surfaces 22, 22’, … continues until the jet reaches the metal base of the second electrode 2. In typical embodiments, the jet will by then be disrupted to such an extent that it is no longer capable of significantly penetrating the metal plate part 29 of the second electrode 2.

As can be seen, the jet 7 of the charge penetrates successive surfaces of the electrically conductive structure, thus producing short-circuits in a stepwise manner. As each successive surface is damaged or destroyed by the jet, the next surface is used to conduct the short-circuit
current. In this way, it is assured that the jet disrupting current is present over a relatively long distance.

In the embodiment of Fig. 1, the arrangements 20, 20′, ... have a height D and are separated from the first electrode 1 by an optional air gap having a height d. The total distance between the electrodes therefore is equal to (D+d). In case the air gap is omitted, the distance between the electrodes equals the height D of the arrangements 20. When the air gap is present, the first electrode 1 and the arrangement 20 are spaced apart by a distance d. When the air gap is not present, the first electrode 1 and the arrangement 1 are not spaced apart but are electrically insulating by the top layer of insulating material 23. It will be understood that in such embodiments this top layer will have to have a sufficient thickness in order to prevent undesired discharges.

The embodiment of Fig. 2 is essentially identical to the one of Fig. 1, with the exception of the stripper plate 3. This plate 3 is arranged between the first electrode 1 and the second electrode 2 to reduce the width of the jet 7. In the example of Fig. 2, the stripper plate 3 is shown to be penetrated by the jet 7. It will be understood that neither the stripper plate 3, nor the first electrode 1, will have an opening before being penetrated by the jet 7.

By providing mechanical resistance, the jet is slowed down and is reduced in width, thus mitigating its destructive effect. The stripper plate 3 is preferably made of armour quality steel or a similar material.

In Figs. 3a-3g various embodiments of the electrically conducting structure 21 are schematically illustrated in side view.

Fig. 3a shows a meandering structure with relatively sharp corners (angles of 90°), while Fig. 3b shows a similar structure with rounded corners. In both embodiments, the surfaces 22 (22′, ...) are arranged substantially in parallel. In both embodiments, the surfaces 22 are electrically in series, and are connected by respective corner sections.
The embodiment of Fig. 3c constitutes a rectangular grid. The surfaces 22 are not only connected at their sides, but also at various places between these sides. In this way, the electrical current can be distributed over the structure.

The embodiment of Fig. 3d is similar to that of Fig. 3c, but constitutes a triangular rather than a rectangular grid. A hexagonal grid is illustrated in Fig. 3e, while grids constituted by arrangements of rounded shapes are shown in Figs. 3f and 3g.

In all embodiments, the distance between two successive surfaces 22, 22', in the penetration direction, preferably lies between approximately 20 and 5 mm and may advantageously lie between approximately 11 and 9 mm. A spacing of about 10 mm between the surfaces results in a time interval between two successive surface penetrations of about 1 s. The present inventors have found this time interval to be advantageous for disrupting the jet while maintaining the current through the jet. However, other spacings can also be used, such as spacings larger than 20 mm.

The thickness of a surface 22 preferably lies between 20 and 5 μm, and may advantageously lie between 11 and 9 μm. A thickness of approximately 10 μm will result in an increased electrical impedance due to heating and/or evaporation, and will thereby assist in commutating the current to the next surface.

It is noted that the electrically insulating material (23 in Fig. 1), in which the structures are embedded to form arrangements 20, may comprise plastic foam or any other suitable material, for example (hard) plastic.

Fig. 3e already showed a hexagonal structure in plan view, as an embodiment of the electrically conductive structure 21. Such a hexagonal structure is shown in perspective in Fig. 4a and illustrates the type of elementary cell out of which the structure 21 can be made up. Another type of elementary cell is illustrated in Fig. 4b, which shows a torus structure in perspective. It will be understood that such torus-shaped elements can be
stacked to form the conductive structure 21. A similar structure is shown in plan view in Fig. 4c. These structure can all be embedded in electrically insulating material to form arrangements 20.

The surfaces of the electrically conductive structure may be constituted by sheets of materials, such as metal foil. The surfaces will be electrically interconnected so as to provide a single electrically conductive structure.

The present invention is based upon the insight that electrically conducting surfaces, which are electrically connected and embedded in an electrically insulating material, cause a stepwise shortening of the electrical path of the current through the electrode as it is pierced by the charge. These electrically conducting surfaces constitute a structure which may be supported by the electrically insulating material. The stepwise shortening of the electrical path causes a very effective disruption of the charge.

It is noted that any terms used in this document should not be construed so as to limit the scope of the present invention. In particular, the words “comprise(s)” and “comprising” are not meant to exclude any elements not specifically stated. Single (circuit) elements may be substituted with multiple (circuit) elements or with their equivalents.

It will be understood by those skilled in the art that the present invention is not limited to the embodiments illustrated above and that many modifications and additions may be made without departing from the scope of the invention as defined in the appending claims.
Conclusies

1. Een elektrisch reactieve bepantsering (10), omvattende een eerste elektrode (1) en een ten opzichte van de eerste elektrode elektrisch geïsoleerde tweede elektrode (2), aan welke elektroden (1, 2) een hoge spanning kan worden aangelegd om een met de elektroden in contact komende lading (7) te verstoren, met het kenmerk, dat de tweede elektrode (2) een elektrisch geleidende structuur (21) omvat met een aantal oppervlakken (22) die in een isolerend materiaal (23) zijn ingebed, zodanig dat de lading opeenvolgende oppervlakken van de elektrisch geleidende structuur doorboort.

2. De bepantsering volgens conclusie 1, waarin de elektrisch geleidende structuur (21) een meanderende structuur omvat.

3. De bepantsering volgens conclusie 1 of 2, waarin de elektrisch geleidende structuur (21) een structuur van verbonden holtes omvat, zoals een honingraat-structuur.

4. De bepantsering volgens een van de voorgaande conclusies, waarin de elektrisch geleidende structuur (21) een aantal elektrisch geleidende elementen omvat die gemaakt zijn van geleidend folie, zoals metaalfolie.

5. De bepantsering volgens conclusie 4, waarin de elektrisch geleidende elementen elk een hexagonale cilinder of een hexagonale torus omvatten.

6. De bepantsering volgens een van de voorgaande conclusies, waarin de tweede elektrode (2) verder een basiselement (29) omvat waarop de elektrisch geleidende structuur (21) is aangebracht en waarmee deze elektrisch is verbonden, welk basiselement (29) bij voorkeur een massieve metalen plaat omvat, met meer voorkeur een metalen plaat van pantserkwaliteit.
7. De bepantsering volgens een van de voorgaande conclusies, waarin de afstand tussen twee opeenvolgende oppervlakken (22, 22'), in de doorboringrichting, tussen 20 en 5 mm ligt, bij voorkeur tussen ongeveer 11 en 9 mm.

8. De bepantsering volgens een van de voorgaande conclusies, waarin de dikte van een oppervlak (22) tussen 20 en 5 μm ligt, bij voorkeur tussen 11 en 9 μm.

9. De bepantsering volgens een van de voorgaande conclusies, waarin de eerste elektrode (1) bij voorkeur door een massieve metalen plaat is gevormd, met meer voorkeur door een metalen plaat van pantserkwaliteit.

10. De bepantsering volgens een van de voorgaande conclusies, verder omvattende een reductieplaat (3) die tussen de eerste elektrode (1) en de tweede elektrode (2) is aangebracht om de breedte van de lading te reduceren.

11. Een stelsel voor het beschermen van een voertuig of vaartuig, welk stelsel tenminste een hoogspanningsbron en een elektrisch reactieve bepantsering volgens een van de voorgaande conclusies omvat.

12. Een voertuig of vaartuig voorzien van een stelsel volgens conclusie 11.

13. Een werkwijze voor het beschermen van een voertuig of vaartuig, omvattende de stap van het toepassen van een stelsel volgens conclusie 11.
An electric reactive armour (10) comprises a first electrode (1) and a second electrode (2) spaced apart from the first electrode, to which electrodes (1, 2) a high voltage can be applied so as to disrupt a charge contacting the electrodes. The second electrode (2) comprises an electrically conductive structure (21) having a plurality of surfaces (22) embedded in an insulating material (23), such that the charge jet penetrates successive surfaces of the electrically conductive structure. The electrically conductive structure (21) comprises a meandering structure and/or a structure of linked cavities, such as a honeycomb structure.

[Fig. 1]
**SAMENWERKINGSVERDRAG (PCT)**

**RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE**

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Aanvrager (Naam)

**Nederlandse Organisatie voor toegepast-natuurwetenschappelijk Onderzoek TNO**

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I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)

Volgens de internationale classificatie (IPC)

| F41H5/007 | F41H5/04 |

II. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimumdocumentatie

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Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

III. GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES (opmerkingen op aanvullingsblad)

IV. GEBREK AAN EENHEID VAN UITVINDING (opmerkingen op aanvullingsblad)

Form PCT/ISA 201 A (11/2000)
ONDERZOEKRAPPORT BETREFFENDE HET 
RESULTAAT VAN HET ONDERZOEK NAAR DE STAND 
VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

A. CLASSIFICATIE VAN HET ONDERWERP 
INV. F41HS/007 
ADD. F41HS/04 

Volgens de Internationale Classificatie van ondernemen (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

B. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimun documentatie (classificatie gevolgd door classificatiesymbolen)

F41H 

Onderzochte andere documentatie dan de minimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte brefwoorden)

EPO-Internal, PAJ, WPI Data 

C. VAN BELANG GEACHETE DOCUMENTEN

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X | Verdere documenten worden vermeld in het vervolg van vak C. 

Verzendingdatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type 

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltoid 

23 januari 2015 

Naam en adres van de instantie 

European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk 

Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016 

De bevoegde ambtenaar 

Giesen, Maarten 

Formulier PCT/ISA/201 (tweede blad) (Januari 2004) 

bladzijde 1 van 2
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This opinion contains indications relating to the following items:

- Box No. I  Basis of the opinion
- Box No. II  Priority
- Box No. III  Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- Box No. IV  Lack of unity of invention
- Box No. V  Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- Box No. VI  Certain documents cited
- Box No. VII  Certain defects in the application
- Box No. VIII  Certain observations on the application

Examined

Giesen, Maarten

Form NL237A (Dekblad) (July 2006)
Box No. I  Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.

2. With regard to any nucleotide and/or amino acid sequence disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:
      
      ☐ a sequence listing
      ☐ table(s) related to the sequence listing

   b. format of material:
      
      ☐ on paper
      ☐ in electronic form

   c. time of filing/furnishing:
      
      ☐ contained in the application as filed.
      ☐ filed together with the application in electronic form.
      ☐ furnished subsequently for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

Box No. V  Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

   Novelty
   Yes: Claims 2-8, 10
   No: Claims 1, 9, 11-13

   Inventive step
   Yes: Claims 2, 3, 5, 7, 8
   No: Claims 1, 4, 6, 9-13

   Industrial applicability
   Yes: Claims 1-13
   No: Claims

2. Citations and explanations

   see separate sheet

NL237B (July 2006)
Box No. VII  Certain defects in the application

see separate sheet
Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

D1 BG 103 643 U (INST METALOZNANIE PRI BAN [BG]) 28 februari 2001 (2001-02-28)
D4 EP 2 290 317 A2 (RHEINMETALL WAFFE MUNITION [DE]) 2 maart 2011 (2011-03-02)

1.

The present application does not meet the criteria of patentability, because the subject-matter of independent claim 1 is not new.

D1 (a machine translation of which is enclosed) discloses

een elektrisch reactieve bepantering, omvattende een eerste elektrode (2) en een ten opzichte van de eerste elektrode elektrisch geïsoleerde tweede elektrode (3,6), aan welke elektroden een hoge spanning kan worden aangelegd om een met de elektroden in contact komende lading (1) te verstoren, waarbij de tweede elektrode een elektrisch geleidende structuur omvat met een aantal oppervlakken (3) die in een isolerend materiaal (7) zijn ingebed, zodanig dat de lading opeenvolgende oppervlakken van de elektrisch geleidende structuur doorboort.
2. Dependent claims 3, 4, 6, and 9 - 12 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of novelty and/or inventive step.

The features of dependent claims 9 and 11 - 12 are known from D1.

The features of dependent claim 3 are known from D3.

The features of dependent claims 4, 6 and 10 are suggested by the combination of D2 and D3.

3. The same reasoning as given in point 1 above applies, mutatis mutandis, to the subject-matter of the corresponding independent method claim 13, which therefore is also considered not new.

4. The combination of the features of dependent claim 2 appears to be neither known from, nor rendered obvious by, the available prior art.

None of the documents cited in the search report disclose the "elektrisch geleidende structuur" to have a "meanderende structuur" in an electric reactive armour.

Although D6 shows a meandering structure, this structure is meant as a crack detection system and not as a charge destroying electrode. Furthermore this structure of D6 is not the second electrode in the sense of the present application. Consequently, the person skilled in the art of electric reactive armour would not consider to combine D6 with any of the documents D1 - D5 for an electric reactive armour.

5. The combination of the features of dependent claim 5 is neither known from, nor rendered obvious by, the available prior art.

None of the documents cited in the search report disclose the conductive elements in an electric reactive armour to comprise a "hexagonale cilinder" or a "hexagonale torus".
6.
Since the features of dependent claim 2 in combination with the subject matter of independent claim 1 and features of dependent claim 5 in combination with the subject matter of independent claim 1 appear to solve the same technical problem, the requirement of unity of invention appears to be met.

It would appear that in the present application two independent claims could possibly have been formulated.

7.
Dependent claims 7 and 8 add additional features to such independent claims.

**Re Item VII**
*Certain defects in the application*

The relevant background art disclosed in D1 is not mentioned in the description, nor are these documents identified therein.